JBACHS
Journal of Basic and Clinical Health Sciences

J Basic Clin Health Sci 2023; 7: 122-130
https://doi.org/10.30621/jbachs.1076294
RESEARCH ARTICLE

THE COMPARISON OF ANAEROBIC POWER USING TWO TESTS IN PATIENTS WITH CYSTIC FIBROSIS AND HEALTHY CHILDREN

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Received: 20.02.2022; **Accepted:** 28.08.2022; **Available Online Date:** 31.01.2023

Cite this article as: Ergin E, Savcı S, Ozcan-Kahraman B, Tanrıverdi A, Mancı E, Ozsoy İ, Atakul G, Volkan A. Asılsoy S, Uzuner N. The Comparison of Anaerobic Power using Two Tests in Patients with Cystic Fibrosis and Healthy Children. J Basic Clin Health Sci 2023; 7: 122-130.

ABSTRACT

Purpose: Cystic fibrosis (CF), a progressive and multi-systemic disease, causes reduced anaerobic performance. This study aimed to compare anaerobic power using two tests (Counter-movement Vertical Jump and Wingate Anaerobic Test) in CF patients and healthy children.
Material and Methods: Eighteen CF and 18 healthy children were included in this prospective study. Knee extensor muscle strength and body composition were assessed using a digital handheld dynamometer and Tanita-BC 418. Anaerobic power was evaluated with the Wingate Anaerobic Test (WAnT) and Counter-Movement Vertical Jump (CMJ) using a triaxial accelerometer (G-Walk)..
Results Maximum concentric power, peak speed, impact force, take-off force, and jump height were significantly worse in the CF group than in their healthy peers ($p<0.05$). CMJ parameters were found to be highly correlated with WAnT parameters, fat-free mass (FFM), body mass index (BMI), and knee extensor muscle strength ($p<0.05$).
Conclusion: The anaerobic power is affected in mild CF patients. CMJ is an easy and effective test to evaluate anaerobic power and compare CF patients and healthy children.

Keywords: Cystic fibrosis, anaerobic power, triaxial accelerometer, counter-movement vertical jump, wingate anaerobic test

INTRODUCTION

Cystic Fibrosis (CF); is a progressive, genetic, and multi-organ disease (1). Airway obstruction due to mucus hypersecretion, oxidative stress, systemic inflammation, malnutrition, and inactivity may contribute to skeletal muscle weakness in CF (2, 3). Impaired anaerobic performance (4), abnormal anaerobic metabolism (5), inadequate aerobic oxidative metabolism due to impaired oxygen delivery (6), or intrinsic abnormalities in muscle function (7), have been reported in CF patients. Decreased anaerobic exercise capacity in CF patients is primarily determined by muscle factors rather than pulmonary function (4, 8). Nutritional status has been identified as a major determinant of anaerobic exercise capacity in CF patients (4). Anaerobic performance in CF was found to correlate with body mass index (BMI) and fat-free mass (FFM) (9).

Daily activities consist of 50-95% aerobic capacity and 5-50% anaerobic capacity. Children's daily activities are characterized by very short physical activity with varying levels of low-to-moderate intensity and repeated anaerobic activities (short sprints or climbing a flight of stairs) rather than sustained aerobic efforts (10). CF children and adult CF patients are unable to participate in moderate-to-vigorous activity compared to their healthy peers (11, 12). Therefore, understanding anaerobic exercise performance may be of more practical importance in the daily life of a patient with CF than an assessment of aerobic exercise endurance (4). It is very important to use valid and reliable tests which assess anaerobic power in CF patients, the improvement in anaerobic exercise capacity can also improve aerobic capacity (13).

The Wingate anaerobic test (WAnT) is used in laboratory settings as an assessment of anaerobic power and capacity (14). Two parameters are determined in WAnT: (a) PP, which is assumed to correspond to the maximum anaerobic power during the test; and (b) MP assumed to be an index of anaerobic capacity (15). However, disadvantages of WAnT are that it is an expensive method, requires equipment that cannot be applied to every population (individuals with insufficient leg length), difficult to perform for children, to apply, and interpret for children due to lack of reference values (16, 17).

The vertical jump test is the most commonly used field test because of the ease of application, especially in school settings, for anaerobic fitness improvements, elite performance sports, talent detection, and multiple-sprint activities (football, rugby, etc.) (18). The vertical jump height has a direct correlation with the amount of force that is produced by muscle fibers (19). During the test, total jump height and peak power can be measured. Compared to WAnT, this test is inexpensive, easy to evaluate, and uses optional equipment (16). Counter-movement vertical jump (CMJ) is an anaerobic power test used in both children and adults (20). CMJ and WAnT are valid and reliable tests used for assessing anaerobic power in healthy children and CF patients (21-24).

A triaxial accelerometer is reliable in characterizing the walking patterns of healthy children (25). Although there are some studies on vertical jump height in CF patients, there is no study measuring maximum concentric power, take-off force, peak speed, and impact force with a triaxial accelerometer. Examining these parameters with a triaxial accelerometer in patients with CF will be important in terms of demonstrating that anaerobic power can be evaluated with an easy and objective test.

This study aimed to compare anaerobic power using tests (CMJ and WAnT) in patients with CF and healthy children. In addition, the relationship between the evaluation parameters of all participants and WAnT and CMJ outcomes was examined.

MATERIAL AND METHODS

Participants' data were retrieved from a previous study (26). This prospective study was conducted between September 2017 to May 2019 at the Dokuz Eylül University Hospital, Izmir, Turkey. The Ethics Committee of Dokuz Eylül University approved all procedures and the experimental design (Decision no: 2017/18-27, Date: 13.07.2017).

Patients were included in the CF group (CFG) if they were 7-18 years, had a diagnosis of CF, and were clinically stable. Patients with acute exacerbations and physical disabilities were not included in the study. Volunteers aged 7–18 years, without any physical disability and systemic disease included in the control group (CG).

The characteristics of CFG and CG were recorded. Body composition was assessed with a body analyzer (TANITA BC 418 MA, Tanita Corporation, Tokyo, Japan) (27).

Respiratory function (FEV1) was assessed using spirometry (SensorMedics, 6200 Body Box, Viasys, Yorba Linda, CA, USA) (28).

Knee extensor muscle strength was assessed with a dynamometer (JTECH, Medical Commander Powertrack II, USA) (29).

WAnT, used to assess anaerobic power, is a cycle ergometer test lasting 30 seconds against constant resistance (Lode, Groningen, Hollanda). Resistance was adjusted according to the participant's body weight, age, and gender. Before starting the WanT, subjects were asked to warm up for 1 minute at 60 rpm against a 15-W resistance. Subjects were asked to pedal as fast as possible after the warm-up.

Anaerobic indices were recorded as mean power (MP) and peak power (PP) by a software program (Wingate 3.1, Lode) (9).

CMJ's instruction was to jump using their arms as high as possible. The highest height (in centimeters) of the three tests was recorded. During the test, maximum concentric power, peak speed, take-off force, jump height, and impact force were measured using a wireless motion measurement device (G-Walk, BTS Bioengineering SpA, Italy) connected to the L4-L5 level of the individual's waist and recorded in the computer program (25).

Table 1. Characteristics of CFG and CG

	CFG (n=18)	CG (n=18)	t/ χ^2	p
Gender			<0.001	0.999¶
Female	9 (50%)	9 (50%)		
Male	9 (50%)	9 (50%)		
Age (years)	13.27 (2.65)	13.22 (2.94)	-0.06	0.953†
Height (cm)	152.66 (15.31)	158.22 (15.22)	1.091	0.283†
Weight (kg)	42.21 (15.79)	52.32 (20.53)	1.655	0.107†
BMI (kg/m2)	17.57 (3.41)	20.07 (4.13)	1.978	0.056†
FFM (kg)	34.16 (11.87)	42.04 (14.28)	1.799	0.081†
FEV1 (L)	2.03 (1.09)	3.00 (1.01)	2.746	**0.002†***
FEV1 (%)	75.61 (27.26)	100.33 (10.73)	3.579	**0.010†***
Knee Extensor Right (kg)	15.06 (5.24)	17.84 (5.65)	1.528	0.136†

All values are expressed as mean (SD). BMI, body mass index; FFM, Fat Free Mass; FEV1, forced expiratory volume in one second; ¶Fisher Chi-Square test, †Independent samples t test,*p<0.05, CFG: cystic fibrosis group; CG: control group.

Statistical analysis

The data were analyzed using SPSS 22.0. Data are expressed as mean and standard deviation (SD). The Shapiro-Wilk test was used to assess normal distribution. To make the comparison between the groups, according to their distribution, Student's T test was used for the parametric variables. Variables determined by counting were compared by the Chi-Square test. Correlations between variables were assessed with Pearson's correlation. Correlation was classed as very high (0.90-1.00), high (0.70-0.89), moderate (0.50-0.69) and weak (0.26-0.49) (30). The significance level was set at p< 0.05

Table 2. Anaerobic power in CFG and CG.

	CFG (n=18)	CG (n=18)	t	p
PP (W)	301.12 (147.57)	385.91 (220.06)	1.358	0.184†
PP (W/kg)	6.91 (1.72)	7.44 (1.83)	0.883	0.383†
MP (W)	227.40 (112.37)	285.27 (156.08)	1.277	0.210†
MP (W/kg)	5.21 (1.39)	5.52 (1.32)	0.684	0.498†
Jump Height (cm)	18.40 (6.40)	24.89 (5.34)	3.305	**0.002†***
Peak Speed (m/sn)	2.10 (0.42)	2.63 (0.33)	4.166	**<0.001†***
TakeOff Force (kN)	0.38 (0.24)	0.67 (0.37)	2.707	**0.011†***
Impact Force (kN)	0.66 (0.36)	0.86 (0.41)	1.557	0.129†
Maximum Concentric Power (W)	1.53 (0.86)	2.56 (1.33)	2.747	**0.010†***

All values are expressed as mean (SD). WAnT, Wingate Anaerobic Test; CMJ, counter-movement vertical jump, †Independent samples t test,*p<0.05, CFG: cystic fibrosis group; CG: control group.

RESULTS

Eighteen CF patients and 18 healthy individuals participated in the study. The characteristics of CFG and CG were shown in Table 1. There was no significant difference in age, gender, weight, height, BMI, FFM, and knee extensor muscle strength between the two groups (p>0.05). FEV1 was significantly lower in CFG than CG (p<0.05).

Table 2 presents the anaerobic power in CFG and CG. There was no significant difference in WAnT PP, MP, and impact force between CFG and CG (p>0.05). CMJ maximum concentric power, peak speed, take-off force, and jump height were significantly lower in CFG (p<0.05).

The association between BMI, FFM, knee extensor strength, CMJ, and WAnT in CFG and CG is shown in Table 3. WAnT PP correlated with FFM, BMI, knee extensor muscle strength, maximum concentric power, peak speed, impact force, take-off force, and jump height (p<0.05) in CFG. WAnT MP correlated with FFM, BMI, knee extensor muscle strength, maximum concentric power, peak speed, impact force, take-off force, and jump height, (p<0.05) in CFG. WAnT PP correlated with FFM, BMI, knee extensor muscle strength, maximum concentric power, impact force, take-off force, and jump height (p<0.05) in CG. WAnT MP correlated with FFM, BMI, knee extensor muscle strength, maximum concentric

Table 3. Anaerobic power in CFG and CG.

		WAnT							
		CFG (n=18)				CG (n=18)			
		PP (W)		MP (W)		PP (W)		MP (W)	
		r	p	r	p	r	p	r	p
BMI (kg/m2)		0.783	**<0.001**$^{\phi*}$	0.777	**<0.001**$^{\phi*}$	0.708	**0.001**$^{\phi*}$	0.706	**0.001**$^{\phi*}$
FFM (kg)		0.911	**<0.001**$^{\phi*}$	0.902	**<0.001**$^{\phi*}$	0.913	**<0.001**$^{\phi*}$	0.904	**<0.001**$^{\phi*}$
Knee Extensor Right (kg)		0.836	**<0.001**$^{\phi*}$	0.850	**<0.001**$^{\phi*}$	0.528	**0.024**$^{\phi*}$	0.508	**0.032**$^{\phi*}$
CMJ	Jump Height (cm)	0.501	**0.044**$^{\phi*}$	0.565	**0.015**$^{\phi*}$	0.631	**0.005**$^{\phi*}$	0.608	**0.007**$^{\phi*}$
	Peak Speed (m/sn)	0.601	**0.008**$^{\phi*}$	0.648	**0.004**$^{\phi*}$	0.242	0.334$^{\phi}$	0.222	0.376$^{\phi}$
	TakeOff Force (kN)	0.773	**<0.001**$^{\phi*}$	0.736	**<0.001**$^{\phi*}$	0.652	**0.003**$^{\phi*}$	0.646	**0.004**$^{\phi*}$
	Impact Force (kN)	0.799	**<0.001**$^{\phi*}$	0.850	**<0.001**$^{\phi*}$	0.526	**0.025**$^{\phi*}$	0.491	**0.039**$^{\phi*}$
	Maximum Concentric Power (W)	0.852	**<0.001**$^{\phi*}$	0.877	**<0.001**$^{\phi*}$	0.738	**<0.001**$^{\phi*}$	0.713	**0.001**$^{\phi*}$

ϕ Pearson correlation analysis, r: Pearson correlation coefficient,*p<0.05, CFG: cystic fibrosis group; CG: control group.

power, impact force, take-off force, and jump height (p<0.05) in CG.

Table 4 presents the relationship between BMI, FFM, knee extensor strength, and CMJ in CFG and CG. In CFG, BMI was correlated with maximum concentric power, impact force, and take-off force (p<0.05). In CFG, FFM was correlated with maximum concentric power, peak speed, impact force, and take-off force (p<0.05). Knee extensor muscle strength correlated with maximum concentric power, peak speed, take-off force, impact force, and jump height (p<0.05) in CFG. BMI correlated with maximum concentric power, impact force, and take-off force in CG. FFM correlated with maximum concentric power, take-off force, impact force, and jump height (p<0.05) in CG. Knee extensor muscle strength correlated with maximum concentric power, jump height, take-off force, and impact force (p<0.05) in CG.

DISCUSSION

In the study, the triaxial accelerometer was used for the first time to evaluate anaerobic power in CF and healthy children. The main finding is that anaerobic power was reduced in mild CF patients. CF patients had similar FFM and knee extensor muscle strength to healthy children. There was a correlation between WAnT and CMJ evaluating anaerobic power in both groups, and CF patients had lower values in CMJ parameters than healthy subjects. Anaerobic power and BMI, FFM, and knee extensor muscle strength were correlated.

BMI and FFM estimation are frequently used to assess nutritional status in CF patients. Although there was no significant difference compared to healthy subjects in this study, CF patients had lower BMI and FFM values. Our results were similar to previous studies evaluating nutritional status in CF (9, 31).

Because of the general decrease in skeletal muscle function in children with CF (32, 33), skeletal muscle dysfunction should also be considered when evaluating anaerobic exercise capacity. Contrary to previous studies, we did not find any significant difference in knee extensor muscle strength between CFG and CG. We thought that the reason was that the patients with CF in this study had mild disease severity and FFM and BMI were similar to those of the healthy children. A study including 33 patients with milder disease suggested that peripheral muscle strength was not significantly reduced (23).

The anaerobic performance consists of anaerobic power and capacity. Anaerobic power reflects the ability to use the phosphagen system, anaerobic capacity, and to derive energy from a combination of anaerobic glycolysis and the phosphagen system. The anaerobic glycolytic system is the primary energy system involved in shorter activities of high intensity and is critically important for high-intensity activities lasting more than a few seconds through to several

Table 4. The relationship between BMI, FFM, knee extensor strength and CMJ in CFG and CG.

		CMJ									
		CFG (n=18)					CG (n=18)				
		Jump Height (cm)	Peak Speed (m/sn)	TakeOff Force (kN)	Impact Force (kN)	Maximum Concentric Power (W)	Jump Height (cm)	Peak Speed (m/sn)	TakeOff Force (kN)	Impact Force (kN)	Maximum Concentric Power (W)
BMI (kg/m2)	r	0.303	0.420	0.837	0.617	0.878	0.239	0.162	0.582	0.638	0.699
	p	0.222[ϕ]	0.083[ϕ]	**<0.001**[ϕ*]	**0.006**[ϕ*]	**<0.001**[ϕ*]	0.339[ϕ]	0.522[ϕ]	**0.011**[ϕ*]	**0.004**[ϕ*]	**0.001**[ϕ*]
FFM (kg)	r	0.429	0.555	0.817	0.751	0.888	0.604	0.382	0.754	0.700	0.867
	p	0.075[ϕ]	**0.017**[ϕ*]	**<0.001**[ϕ*]	**<0.001**[ϕ*]	**<0.001**[ϕ*]	**0.008**[ϕ*]	0.118[ϕ]	**<0.001**[ϕ*]	**0.001**[ϕ*]	**<0.001**[ϕ*]
Knee Extensor Right (kg)	r	0.532	0.545	0.628	0.759	0.810	0.531	0.462	0.655	0.687	0.746
	p	**0.023**[ϕ*]	**0.019**[ϕ*]	**0.005**[ϕ*]	**<0.001**[ϕ*]	**<0.001**[ϕ*]	**0.023**[ϕ*]	0.053[ϕ]	**0.003**[ϕ*]	**0.002**[ϕ*]	**<0.001**[ϕ*]

ϕ Pearson correlation analysis, r: Pearson correlation coefficient,*p<0.05, CFG: cystic fibrosis group; CG: control group.

minutes as well as in activities that are typical of the nature of children's play (34). WAnT is a reliable and valid test for the anaerobic glycolytic system (22). It has been reported that children with CF with poorer lung function or aerobic exercise capacity use less aerobic energy stores and rely more on glycolytic systems during WAnT, which may be due to the underlying physiological sequelae of chronic obstructive pulmonary disease (21). Defects in both anaerobic and aerobic metabolism have been demonstrated including a decreased resting Adenosine Triphosphate/Phosphocreatine (ATP/PCr) ratio and ATP concentrations and slower recovery of PCr following anaerobic exercise (35). Selvadurai et al. (5) noted that mitochondrial oxidative metabolism in CF patients is inefficient and requires the use of more phosphocreatine stores to perform the same amount of work as healthy control subjects.

CMJ and WAnT tests to rely heavily on ATP/PCr energy system contributions to produce/sustained maximal anaerobic power (16). WAnT is a valid and reliable anaerobic performance test in children and adults with chronic diseases (22). Anaerobic peak power has been measured in children with CF using WAnT (9, 21, 36, 37). Boas et al. (21), evaluated aerobic and anaerobic capacities in mild CF, asthmatic patients, and healthy children, and three groups had similar VO2max, PP, and MP in the normal range. WAnT values were similar in both groups in this study.

CMJ is often used to evaluate anaerobic power in both children and adults (20). Arikan et al. (38), found a significant difference in jump height between CF and healthy individuals. In our study, the healthy group had significantly higher maximum concentric power, peak speed, take-off force, and jump height. The CMJ test also has disadvantages; at the peak of the jump, the subject must time the jump to mark the wall, or the exact peak height of the jump may not be measured (39). The use of motion sensors to evaluate CMJ has several advantages; motion sensors are small, portable, wearable devices that can provide metrics for other aspects of the CMJ besides jump height (40). This study is the first to assess maximum concentric power, peak speed, impact force, take-off, and jump height, obtained by using a triaxial accelerometer (G-Walk) in patients with CF and healthy children.

Boas et al. (8), stated that CF patients with BMI above 17.5 kg / m2 had higher PP and MP, and nutritional status had an important role in determining anaerobic performance. Klijn et al. (9), found that spirometric variables and FFM were the determinants of anaerobic exercise performance in CF patients and that 77-82% of the anaerobic exercise was explained by FFM. Klijn et al. (9) stated that not all muscle groups are equally important in evaluating anaerobic performance. Knee extensors are the most important muscle group during sprinting on a bicycle ergometer. In our study, positive correlations were found between FFM, BMI, knee extensor muscle strength, and CMJ and WAnT parameters. We thought that the WAnT parameters of the two groups were similar because the knee extensor muscle strength and especially the nutritional status of CF patients, such as FFM, are similar to healthy individuals.

Hoffman et al. (41) found significant positive correlations between CMJ and both PP and MP in basketball players. Nikolaidis et al. (42) stated that CMJ correlated with PP in adolescent volleyball players. Alemdaroglu stated that PP significantly correlated with CMJ and isokinetic concentric knee extension strength in basketball players (43). Changela et al. (16) stated that there was a significant positive correlation between the vertical jump test and WAnT in high school basketball players, demonstrating the validity of the vertical jump as a field test of anaerobic power. Eyüboglu et al. (44) found that WAnT was correlated with vertical jump height. In our study, a positive correlation was found between WAnT and CMJ. In the post-hoc power analysis, the power of our study for vertical jump height was 97.5%. However, to conduct comparative studies between WAnT and CMJ, it will be important to determine the validity and reliability of the triaxial accelerometer used in CMJ on a larger number of individuals.

Many studies compare WAnT and CMJ tests in terms of sport specificity. Jumping is a widely used physical activity and is appreciated in children and adolescents (45). Physical activity in which children participate, jumping and running were found to be the most frequently used locomotor skills in structured and unstructured play (46). Knowledge of the relationship between CMJ and WAnT tests would contribute to an optimal measurement and evaluation of anaerobic power, which would be of great practical value in the clinic. Thus, we believe that CMJ, which is an easy-to-perform test that includes children's favorite activities can be used frequently in the clinic for anaerobic power assessment of children in cases where WAnT cannot be applied. In this respect, we believe that the study will be a guide for new research on the clinical application of CMJ.

Limitation of this study; we did not include severe CF patients, it would be better to see the relationship between WAnT and CMJ parameters in severe CF patients. The second limitation of this study was that in addition to the knee extensor muscle strength, the strength of other muscles in the lower extremity, such as the hip extensor muscle strength, could be measured.

As a result; BMI, FFM, and knee extensor muscle strength were correlated with decreased anaerobic power in mild CF patients. There was a correlation between WAnT and CMJ assessing anaerobic power in both groups.

CONCLUSION

In conclusion, respiratory functions and anaerobic power were affected in CF patients. Body composition and knee extensor muscle strength have a significant role in determining anaerobic power. This is the first study using the triaxial accelerometer to measure CMJ in CF and healthy children. In light of the extensive research that needs to be done, we believe that the CMJ can be used to assess children's anaerobic capacity in clinical settings where WAnT cannot be used. In this regard, this study will serve as a model for future research on the use of vertical jump tests in clinical settings. In addition, we think that our study will promote information about exercise programs in terms of the ease of use of CMJ with the triaxial accelerometer and guide outcome measures to be used to evaluate the effectiveness of physical therapy interventions in patients with CF.

Acknowledgement: This work was supported by the committee of Department of Scientific Research Coordination Unit of Dokuz Eylül University under grant number 2018.KB.SAG.020. We acknowledge Department of Scientific Research Coordination Unit of Dokuz Eylül University for supporting the purchase of a triaxial accelerometer. We thank all our patients and volunteers for their participation.

Author contribution: Ezgi ERGIN: Contributed to conception and design, supervision, materials, data collection and processing, analysis and interpretation, literature review, writing, critical review and gave final approval and agree to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Sema SAVCI: Contributed to conception and design, supervision, analysis and interpretation, literature review, writing, critical review and gave final approval and agree to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Buse OZCAN KAHRAMAN: Contributed to supervision, analysis and interpretation, writing and gave final approval and agree to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Aylin TANRIVERDI: Contributed to data collection and processing, analysis and interpretation and gave final approval and agree to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Egemen MANCI: Contributed to data collection and processing and gave final approval and agree to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved. İsmail OZSOY: Contributed to data collection and processing and gave final approval and agree to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Gizem ATAKUL: Contributed to materials and gave final approval and agree to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Ayşe VOLKAN:

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Conflict of interests: The authors declare that there is no conflict of interest.

Ethical approval: This study was approved by the research ethics committee of the Faculty of Medical Sciences of Dokuz Eylül University (Decision no: 2017/18-27, Date: 13.07.2017).

Funding: This work was supported by the committee of Department of Scientific Research Coordination Unit of Dokuz Eylül University under grant number 2018.KB.SAG.020. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Peer-review: Externally peer-reviewed.

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